New Earth Science Data and Access Methods

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Abstract— **NASA's Earth Science Enterprise, working with its domestic and international partners, provides scientific data and analysis to improve life here on Earth. NASA provides science data products that cover a wide range of physical, geophysical, biochemical and other parameters, as well as services for interdisciplinary Earth science studies. Management and distribution of these products is administered through the Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Centers (DAACs), which all hold data within a different Earth science discipline. This paper will highlight selected EOS datasets and will focus on how these observations contribute to the improvement of essential services such as weather forecasting, climate prediction, air quality, and agricultural efficiency. Emphasis will be placed on new data products derived from instruments on board Terra, Aqua and ICESat as well as new regional data products and field campaigns. A variety of data tools and services are available to the user community. This paper will introduce primary and specialized DAAC-specific methods for finding, ordering and using these data products. Special sections will focus on orienting users unfamiliar with DAAC resources, HDF-EOS formatted data and the use of desktop research and application tools.**

NASA Earth Science, EOS, Agricultural Efficiency, Air Quality, Coastal Management, Water Management

I. INTRODUCTION

NASA's Earth Science Enterprise (ESE), working with its domestic and international partners, provides scientific data and analysis to improve life on Earth. NASA provides a collection of science data products that cover a wide range of physical, geophysical, biochemical and other parameters, as well as services for interdisciplinary Earth science studies. Management and distribution of these products is administered through the Earth Observing System Data and Information System (EOSDIS) Data Centers, which all hold data within a different Earth science discipline. NASA's exploration is ongoing with plans for addition of new observations and new instruments. Applications implementation is the pioneering work to realize our investment in space-based remote sensing.

I. ESSENTIAL SERVICES/APPLICATIONS

A. Agricultural Efficiency

NASA's space-based Earth Observing Satellite (EOS) measurements can be used to better monitor and forecast global and domestic agricultural production. Instruments onboard several EOS satellites measure important parameters such as global seasonal surface temperature, soil moisture, water availability, biomass, land cover/usage, land surface topography, ocean surface currents, global precipitation, evapotranspiration and radiation, vegetation indices and leaf area index leading to increased agricultural productivity and reliability and improved crop production assessments. The value and benefits of these data are far reaching in that we can now predict and monitor early warning of problems within major agricultural commodities, we have better seasonal yield estimates, we are able to detect vegetation anomalies, and through assimilation methods we are able to create a multi-year time series of crop comparisons.

For many agricultural regions, water availability is a function of winter snow cover as seasonal snowmelt is the main source for crop irrigation. NASA's Moderate Resolution Imaging Spectroradiometer (MODIS), flown on both the Terra (from 2000) and Aqua (from 2002) satellites, collects daily global data on vegetation condition, surface temperature, snow cover, and evapotranspiration.

MODIS/Terra Snow Cover 8-Day L3 Global 500m Grid (MOD10A2) data improves the monitoring and forecasting of agricultural production with its snow cover measurements. The MOD10A2 data includes observations of snow occurrence and the maximum snow cover extent for the 8-day period it represents. Each granule of MOD10A2 is a 1200 km by 1200 km gridded tile. Because of the improved spatial resolution of the MODIS snow cover products, MOD10A2 can be combined with direct visible reflectance property data providing a timely assessment of current conditions with minimal cloud cover. Snow depletion time series curves can be created from the MOD10A2 data that relate the percent of a basin or zone covered by snow during the snow melt season. These time series provide an indication of the temporal and spatial extent of seasonal snow pack available for irrigation.

The U.S. Agency for International Development (USAID)-funded Famine Early Warning System Network (FEWS NET) project is an example of a project that currently uses

MOD10A2 data. The FEWS NET project works with partners in the United States, Africa, Afghanistan, Central America, and the Caribbean to provide early warning about food insecurity to decision makers. FEWS NET uses MOD10A2 to determine the availability of water for irrigation as an early indicator of potential threats to food security in Afghanistan.

MOD10A2 is archived at NASA's National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC) at the University of Colorado. The data can be found online using the NSIDC DAAC Data Pool, a short-term data cache that provides FTP access to selected data, http://nsidc.org/data/data_pool/index.html. The data can also be ordered using the general access methods described in Section III. or from NSIDC DAAC's SNOW-I and MODIS SNOW-I search and order clients http://nsidc.org/data/modis/order.html.

The MODIS sensor can also provide information on terrestrial vegetation by monitoring water-stressed regions through derived products, such as the leaf-area index and the normalized vegetation index. Plant greenness in the form of vegetation index values provides correlative information about plant growth and stress. Vegetation index, solar radiance, and surface temperature data can be combined to forecast crop yields.

MODIS/Terra Vegetation Indices 16-Day L3 Global 500M (MOD13A1) and MODIS/Terra Vegetation Indices 16-Day L3 Global 250M (MOD13Q1) data improve the monitoring and forecasting of agricultural production by providing photosynthetic plant activity (vegetation condition) measurements. Difference maps can be created from either MOD13A1 or MOD13Q1 by subtracting the pervious time period's (e.g. year, 16 days) vegetation indices from the current time period's vegetation indices. The difference maps show the condition of vegetated areas (e.g. cropped areas).

The following tools are available to make the data readily usable in the field. The LP DAAC's MODIS Reprojection Tool (MRT) can subset, geographically project, and reformat MODIS data from the Hierarchical Data Format EOS (HDF-EOS) file format to GeoTIFF or raw binary. Display tools are used to generate graphics and compute differences in seasonal images for visual inspection. The data can be displayed easily on desktop computers using the GeoTIFF or raw binary output from the MRT. Quality information (QA) (e.g. vegetative index quality, aerosol quality, mixed cloud presence, land/water flag, possible snow/ice) associated with the data is used to determine the value of the data for particular applications. QA information can be extracted using the Land Data Operational Product Evaluation (LDOPE) tool. These tools can be found at http://edcdaac.usgs.gov/datatools.asp.

MOD13A1 and MOD13Q1 are used in the FEWS NET project mentioned above to monitor growing season conditions in Afghanistan, Central America, the Caribbean, and Africa.

This data is archived at NASA's Land Processes (LP) DAAC at the United States Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center (EDC). The data can be found online using the LP DAAC Data Pool, http://edcdaac.usgs.gov/datapool/datapool.asp. The data can also be ordered using the general access method described in Section III.

B. Air Quality

Most air toxins originate from anthropogenic sources (e.g. fossil fuel burning, chemical manufacture), but some air toxins originate from natural resources such as volcanic eruptions, forest fires and plant bioaerosols; human activities also have a direct and indirect impact on air quality. By improving our remote sensing capabilities, observations of aerosols, ozone and precursor gases, and trace gases lead to a better understanding of the natural and human impacts on the chemical composition of the Earth's atmosphere.

Measurements Of Pollution In The Troposphere (MOPITT), an instrument on the Terra spacecraft, measures the global carbon monoxide (CO) distributions in the troposphere. CO is a significant factor in air pollution. MOPITT Derived CO and CH4 (MOP02) Level 2 data improves our ability to analyze and forecast air quality with its CO measurements. MOP02 is most accurate between 2 and 8 km above the Earth's surface. The CO pollution exposed with the MOP02 data product can come from a variety of sources (e.g. CO plumes from industrial regions, CO plumes transported from their biomass fires origin). However, sometimes it is difficult to differentiate pollution associated with a particular city and background pollution that originates from the surrounding areas. In applications, MOP02 is temporally and spatially averaged over a period of time to lessen the role of the various transported background pollution, to make the measurement at a specific site more accurate, and to establish a complete image that was originally lacking, due to cloud contaminated data gaps. The value of MOPITT observations is in the ability to track CO plume dispersal regionally and globally. For example, the MOP02 data has shown that the topography of the CO plume area can have a negative effect on the overall air quality in the region.

Numerous projects are using MOPITT data to monitor CO plumes and thus the concentration of air toxins for air quality applications. Clerbaux et al [1] analyzed CO concentrations using MOP02 measurements over time for selected cities (e.g. Mexico City) and remote areas to track pollution plumes from urban areas. Lamarque et al [2] used MOP02 to study the dispersal of CO from forest fires in Montana and Idaho. Using MOP02 data, Larmaque et al showed that the CO plume from the observed fire moved eastward, arriving at the United States' East coast a couple of days later and that the resulting CO from wildfires greatly impact the troposphere during the summer months.

The MOPITT L2 Viewer tool can be used to map images from the MOPITT Level 2 data files. The Sample Read Software tool can be used to extract information from MOP02 data that will be outputted in ASCII and can provide basic latitude-longitude subsetting. These tools can be found at http://eosweb.larc.nasa.gov/PRODOCS/mopitt/table_mopitt.html.

MOPITT is archived at NASA's Atmospheric Sciences Data Center (ASDC) DAAC at NASA's Langley Research Center (LaRC). The data can be found online using the ASDC

DAAC Data Pool, http://eosweb.larc.nasa.gov/HPDOCS/datapool/. The data can also be ordered using the general access methods described in Section III.

C. *Coastal Managementt*

Our coastal zones represent precious natural resources. Human population expansion and land development alter the coastal landscape and coastal ecosystem and are linked to the current health of the world's oceans which are showing serious signs of stress. Newly emerging remote sensing technologies are providing scientists with the necessary tools to monitor the health of our coastal zones. NASA satellite measurements such as sea surface temperature and salinity, sea surface height, ocean winds (near surface wind vectors, etc), ocean color, and precipitation enable us, jointly with our partnering agencies, to create decision support models that preserve our coastal ecosystem.

Sea-viewing Wide Field-of-view Sensor (SeaWIFS), an instrument on the OrbView-2 satellite launched in 1997, provides 1.1 km resolution data on global bio-optical properties of the ocean. SeaWIFS Level 3 8-day Binned Photosynthetically Active Radiation (PAR) data improves our ability to preserve and protect the coastal ecosystem with its long-term ocean color measurements. SeaWIFS PAR data are false color representations of pigment concentrations in the ocean (i.e. sea surface color). Ocean color is a function of the presence of particles in the water and phytoplankton make up a large portion of particles present. SeaWIFS PAR can be used to calculate the concentration of biomass on the ocean surface. The SeaWIFS PAR data coupled with sea surface temperature measurements are inputs to a light-photosynthesis model to derive net primary production (NPP), which is the key indicator for biological activity. NPP, in some areas of the world, describe local food availability better than the chlorophyll concentration measurements for ocean mammals and some fish and shellfish species. Food availability plays a vital role in the sustainability of the coastal ecosystem.

Littaye et al [3] used SeaWIFS PAR data to study and explain the fin whale summer distribution in the northwestern Mediterranean Sea during the summer months. SeaWIFS PAR was used in this study to calculate net primary production. Littaye et al presents evidence that fin whale movements are dependent on food availability rather than environmental conditions.

The WIM (Windows Image Manager) tool can be used to visualize and analyze SeaWIFS data, http://spode.ucsd.edu/index.html.

SeaWIFS PAR is archived at NASA's Goddard Space Flight Center (GSFC) Earth Sciences (GES) DAAC. The data can be ordered at http://daac.gsfc.nasa.gov/data/dataset/SEAWIFS/ or using the general access methods described in Section III.

Advanced Very High Resolution Radiometer (AVHRR) Oceans Pathfinder Global Equal Angle Best SST (NOAA/NASA) Level 3 8-day data measures sea surface temperature (SST). AVHRR Pathfinder SST is particularly useful for long-term time series studies in that the AVHRR has been cross-calibrated since its launch, so its measurements provide an accurate basis for analysis.

Littaye et al [3] used temporally and spatially coincident AVHRR Pathfinder SST data in the summer distribution of fin whale project. AVHRR Pathfinder SST was used for calculating NPP and as a guide to the vertical movement of the ocean due to wind, which in turn effects the vertical movement of the food source.

The WIM tool can also be used with the AVHRR Pathfinder SST data. In addition, PO.DAAC Ocean ESIP Tool (POET) provides subsetting and visualization capabilities for PO.DAAC datasets.

AVHRR Pathfinder SST is archived at NASA's Physical Oceanography (PO) DAAC at the Jet Propulsion Laboratory (JPL). The data can be found online at ftp://podaac.jpl.nasa.gov/pub/sea_surface_temperature/avhrr/pathfinder/. The data can also be ordered using the general access methods described in Section III.

D. *Future Applications – Water Management*

Instruments onboard several NASA EOS satellites measure the key parameters needed to improve water resource assessments in data sparse areas. MODIS on Terra and Aqua provide morning and afternoon observations of snow cover extent. Maurer et al [4] has shown the potential for as much as 15% improvement in classification of snow for basins that already have fairly good network of ground observations (approximately 500 meter accuracy).

Recent advances in remote sensing technology allow us to better measure soil moisture, evapotranspiration, precipitation, snow cover accumulation, and water equivalent, necessary for improving water management practices. The Advanced Microwave Scanning Radiometer - EOS (AMSR-E) instrument on Aqua provides new observations for water management applications (e.g. precipitation, total integrated water vapor, cloud water content, snow cover water content, sea ice, and land surface wetness).

The AMSR-E datasets provide a new, unique opportunity for improving water resource monitoring. With this new high-resolution passive microwave instrument, resource managers can obtain higher resolution observations for snow and ice fields using AMSR-E. National scale and hemispheric models are moving from the current 23 KM resolution grids (seen with Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) data) to higher resolution 13 KM grids.

The measurements from AMSR-E/Aqua Daily Level 3 Global Snow Water Equivalent EASE Grid (AE_DySno) are useful for deriving new information about snow depth that can be assimilated into existing snow cover models and applications. Scientists at NSIDC are developing a blended snow cover product that combines snow extend data derived from MODIS visible-spectrum sensors with snow water equivalent data derived from AMSR-E products.

NASA validation efforts on AMSR-E soil moisture products plan to demonstrate applications over the next year by assimilating AMSR-E data into hemispheric and local watershed models. To date, AMSR-E surface soil moisture and vegetation water content in the EASE Grid have shown success in validation studies for deriving effective moisture values as part of AMSR-E data Soil Moisture Experiments in 2002.

AMSR-E is archived at NASA's NSIDC DAAC. The data can be found online using the NSIDC DAAC Data Pool, http://nsidc.org/data/data_pool/index.html. The data can also be ordered using the general access methods described in Section III. or from NSIDC DAAC's SNOW-I and MODIS SNOW-I search and order clients,

http://nsidc.org/data/modis/order.html.

II. NASA EOS Data Access

All of the data referenced in this paper are archived at the ESE Data Centers and can be ordered using the Earth Observing System (EOS) Data Gateway (EDG). EDG is the primary way to access NASA's EOS data archived at the Data Centers. The data is in HDF-EOS format and can be ordered using a variety of ordering options (e.g. FTP, CD-ROM, DLT, DVD, or 8-mm tape). The EDG is located at http://eos.nasa.gov/imswelcome.

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